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A Method of Assessing Risk in Forestry Investments

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SUMMARY

A method for evaluating investments that considers associated risks is described and its application to forestry illustrated. The outcome of many forestry investments is highly uncertain because of the long production period involved. Nevertheless, forest managers often rely on a single predicted rate of return as the best estimate of the payoff using that value as if it were certain. None of the methods used for recognizing risk indicate the chances of achieving the predicted rate of return. David B. Hertz, a management consultant, developed a practical means for computing the odds of achieving the expected return from an investment. The technique, which incorporates risk information and Monte Carlo simulation, can be applied by forest managers to make better choices.

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INTRODUCTION

When costs are accelerating and market interest rates for capital are high, refined techniques for analyzing forestry investments are essential. Competition for available capital is keen and forest managers, who have little direct control over the size of their budgets, must present complete, rational analyses to convince decision makers, unfamiliar with forestry, of the desirability of proposed investments. Investment decisions are also challenging because of the difficulty of attaining long-term investment objectives when unwise investments are not easily avoided and very costly when they occur. To screen investment proposals with greater precision, forest managers need a technique that enables them to not only predict rates of return but also indicates the likelihood of their being achieved.

Knight, in *Risk, Uncertainty, and Profit,* a book which has become a classic of economic literature since its publication in 1921, pointed out that the time required for the production of a good introduces uncertainty (Knight 1921), and the longer the interval before the outcome is known, the less certain the outcome. Since timber growing is one of the longest production processes employed by man, uncertainty is always present.

Knight recognized two classes of uncertainty in investments: measurable and unmeasurable (Knight 1921). The term "risk" designated the former, and the term "uncertainty" the latter.

Worrell applied Knight's classifications to situations in forestry where knowledge about future outcome is lacking (Worrell 1959). He gave as examples of uncertainties: technological changes, sociological changes, and legal changes. He separated risks into two types. One type of risk exists when the characteristics of the outcomes are known in advance. For example, when germination tests show that 75 percent of the slash-pine seed collected in an area during a particular year is viable, the nursery manager can plant one-third more seeds than the number of seedlings desired. The second type of risk is that for which statistical probabilities can be established, such as destruction by forest fires, but an individual owner does not know when or if fire will strike his forest.

Although foresters have long been aware of risk in forestry investments, risk has usually not been formally incorporated into investment analyses. The deterministic models commonly used are based on the twin assumptions of complete knowledge and certainty of future events. Even though the model may be mathematically precise, it predicts only a single rate of return, considered to be the "best estimate." When faced with single estimates, those who make investment decisions may protect themselves against selecting any of the riskiest investments by setting a high expected rate of return that must be reached or exceeded for a proposal to be accepted.

A commonly applied technique to account for risk in forestry is adjusting the discount rate by adding a premium. Where the interest rate is low and duration of the investment short, this is an acceptable and reliable method. Where these two conditions do not exist, however, the allowance for risk is often much too great (Duerr 1950, Guttenberg 1950). An alternative is to either scale down prospective returns or scale up costs.

Another method frequently used to recognize risk is to calculate rates of return based on high and low values. Although the pessimistic and optimistic estimates indicate the possible range of results, they do not indicate which is most likely to occur.

None of the conventional techniques provide decision makers with a realistic measurement of the risks involved in selecting opportunities for capital investment. The reason is easily explained with an example. If six factors have been identified as significantly affecting the outcome of a particular investment and the expected value for each has a 60 percent chance of occurring, conventional analysis would pre-

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dict the actual outcome less than 5 percent of the time ($0.6^6 = 0.047$).

An ideal method for evaluating forestry investments would explicitly consider risk. A method that does this was developed by David B. Hertz, a management consultant (Hertz 1964).

This paper describes the Hertz method and illustrates its application to capital investments in forestry.

THE HERTZ METHOD

The Hertz method is a computer-based capital investment risk analysis procedure involving Monte Carlo simulation. Monte Carlo simulation is a technique for numerically exploring a system by repeatedly sampling proabiltiy distributions of the variates specified in the model. This paper describes the process in detail.

The two initial steps in the process are to indentify both cost and income variables affecting the outcome of investment, and to construct a risk profile for each variable. This is done by collecting all available information from historical trends, statistical studies, management records, experienced judgments, and other sources, and then weighing and combining the information.

A risk profile can be represented as a probability distribution curve with the range of outcomes measured along the horizontal axis, and the chances of each outcome value being achieved measured along the vertical axis. A risk profile for sawtimber stumpage, for example, may show that the chance of the price being $100 per thousand board feet at harvest is 20 percent, while the chance of being $150 is only 5 percent. Risk profiles for various input factors may be bell-shaped, arcs, horizontal lines, or have other forms.

In the third step, one value is randomly selected for each independent variable from its risk profile. The set of values selected are then used, in the fourth step, to calculate the rate of return on investment by conventional present net worth, internal rate of return, or composite rate of return procedures.

These four steps, (a) identifying the significant independent variables that determine investment outcome, (b) constructing risk profiles for each key input factor, (c) randomly selecting one value from the probability distribution for each factor, and (d) combining the selected values to calculate a return on investment, are the basic procedures involved. The remaining steps are based on the repetition of steps three and four in which the computer repeats the process of selecting additional sets of values (Step 3) and calculating a new rate of return for each set (Step 4). After several thousand rates of return have been calculated, the computer lists the results from the highest to the lowest. From this ranking, the percentage of total situations falling within given ranges of rates of return are determined.

Finally, the probability of occurrence for each range of rates of return is cumulated to derive a risk profile for the proposed investment. The risk profile will show the chance of earning any given rate of return from the investment. It will also show the maximum return which can be earned as well as the chance of incurring a loss.

A FORESTRY ILLUSTRATION

To demonstrate the Hertz method, an investment in a slash pine plantation was hypothesized. It was assumed the plantation was established on Site Index 60 (25 years) land in the West Gulf Region, and was expected to be harvested in 30 years. The results are not intended to indicate the profitability of growing slash pine in the West Gulf Region.

In this illustration, each step involved in the Hertz method, as applied to a forestry investment, is described in detail.

The composite rate of return earned on the investment is determined by the present worth of all costs, and the value of the plantation at harvest.[1] Probability distributions of expected costs per acre were established in consultation with experienced, professional forest managers (table 1). It was assumed approximately 650 trees would be planted per acre at 8 × 8 foot spacing using seedlings grown in a contract nursery from seed furnished by the firm.

There are two ranges of planting costs: lower costs for machine planting and higher costs for hand planting. Three-quarters of the seedlings are to be machine planted.

Contract costs of site preparation were estimated to range from $60 to $80 per acre.

Annual property taxes levied by local government are the major variable in determining annual costs of management. *Ad valorem* taxes range from less than $1 per acre per year to more than $5.

Conventional investment analyses rarely include "unlikely" costs, but risk analysis can incorporate them. For example, replanting with no additional site preparation was assumed to be necessary 28 percent

[1]For a discussion of composite internal rate of return see Marty, Robert. 1970. The composite internal rate of return. Forest Science 16:276–279.

Table 1.—*Expected slash pine plantation establishment and management costs in West Gulf, with associated probabilities of occurrence*

Cost factor	Cost	Year of occurrence	Probability of occurrence
	$/acre		
Planting stock	5.85	0	.10
	7.15	0	.20
	7.80	0	.70
Planting	11.00–18.50	0	.75
	22.00–25.00	0	.25
Site preparation	60.00–67.00	0	.30
	67.01–73.00	0	.40
	73.01–80.00	0	.30
Management	3.00–3.50	Annual	.25
(taxes, annual	3.51–4.00	Annual	.33
overhead, protection	4.01–4.50	Annual	.25
and other yearly	4.51–5.50	Annual	.15
outlays)	5.51–8.00	Annual	.02

of the time; 18 percent after the first growing season and 10 percent after the second. It is also assumed that a chemical release is necessary in the fifth year on 10 percent of the plantations. The cost is $21.80 to $28.68 per acre (Moak et al 1977). Finally, the loss of plantations due to catastrophe or changing land use before any return can be earned is expected to occur 5 percent of the time.

Costs that occur during the life of the stand were discounted to the present at a 10 percent rate.

Similarly, probability distributions were determined for factors affecting revenues (tables 2 and 3). The plantations were expected to grow at an average rate of from 50 to 100 cu. ft. per acre per year, as suggested by regional studies (Dutrow 1978). All surviving trees will be harvested 30 years after initial planting with no intermediate thinnings.

Thirty-year-old slash pine plantations can be expected to yield some saw log material. For stands having an average of 300 surviving trees per acre at time of harvest, a ratio of pulpwood-to-sawlog volume of 80:20 was assumed.

Twenty percent of the total stand volume for plantations with 300 surviving trees per acre is represented by trees 11-inches d.b.h. and larger and utilized to a 4-inch top. Ratios of pulpwood-to-sawlog volumes were computed for other average survival rates assuming the minimum diameter for sawtimber trees is 11 inches. Stands with fewer surviving trees will have less total volume but a larger average diameter (Dell et al 1979) and a higher ratio of saw timber volume, while stands with a greater number of trees have more volume but small diameter trees and a lesser proportion of saw timber.

Harvest values per acre in dollars per cubic foot (table 3) are based on June 1979 prices from *Timber Mart South* for South Mississippi, Southeast Louisiana and Southeast Texas (Timber Mart South 1979). Conversions from cord to cubic values assumed 65 cubic feet per cord.[2] Scribner values were converted using the following board foot:cubic foot conversions by diameter class:

4.85:1 11-inch d.b.h.
5.10:1 12-inch d.b.h.
5.35:1 13-inch d.b.h.

Once the key input factors determining costs and revenues for the investment were identified and uncertainty profiles estimated for each, the next step was to select one value for each factor. The initial values selected at random were:

Cost of planting stock	$ 7.80	per acre
Average cost of planting	$12.88	per acre
Cost of site preparation	$73.00	per acre
Annual costs of management	$ 4.00	per acre
Volume	24.6	CCF per acre
Value of output	$ 0.320	per cu. ft.

The composite internal rate of return is then calculated for this combination of values by using the formula:

$$(1 + R)^{30} = \frac{FVI}{PVC}$$

where:

R = composite internal rate of return
FVI = future value of all incomes
PVC = present value of all costs.

The values of these variables were calculated to be $131.39 for PVC and $787.20 for FVI. When these two values were substituted in the rate of return equation, the value of R was found to be 6¼ percent.

The process of selecting a set of values and calculating the rate of return is repeated 10,000 times, a task easily and quickly accomplished by computer.

In the computer program (Appendix) the Monte Carlo simulation uses a random number generator with a subroutine to select costs that are discounted when necessary and summed to determine present worth. It also uses a subroutine to compute future values by selecting the volume range according to probability of occurrence, and then selecting a volume within the range at random. If the plantation was selected for replanting, the expected volume is reduced as follows:

[2]The U.S. Forest Service conversion factor of 1.54 cords per 100 cu. ft. of solid wood (65. cu. ft. per cord) is used by Region 8 (Southern Region) in the sale of small roundwood (pulpwood) timber.

15.0–20.6 C cu. ft.	50 cu. ft. per acre per year
20.7–24.6 C cu. ft.	70 cu. ft. per acre per year
24.7–30.0 C cu. ft.	90 cu. ft. per acre per year

Next, a value class is selected according to probability, and a value is selected within the range at random. The volume is multiplied by this value. The rate of return is computed by assigning a negative rate 5 percent of the time to account for plantation loss due to catastrophe or reversion to another land use. The investigator can experiment with the number of computations until the distribution of results indicates that virtually all possible combinations of significant factors have been sampled.

The computer then lists each composite rate of return result, from highest to lowest (table 4). Of the 10,000 calculations made for this investment, 503 resulted in negative returns. From the frequency table, showing the possible financial outcomes for this investment, the computer determines the percentage of each falling within given ranges of the positive rate of return, i.e., the probability of their occurrence.

Finally, these percentages are summed to obtain the cumulative probability (table 5) and used to derive a risk profile for the investment (fig. 1). This curve shows the highest return possible and the range of returns. More importantly, it shows the chances of equalling or exceeding a particular rate of return.

This method of risk analysis provides decision makers with more useful information than a conventional analysis. Conventional analysis, using "most likely" numbers, would predict an expected return of about 5.1 percent. The results of risk analysis, using 10,000 iterations, indicates that a return of precisely 5.1 percent can be expected to occur only about 5 percent of the time (table 4). Risk analysis also shows that returns from 2.1 to 7.9 percent are possible. The decision maker will be more interested in learning that 5.1 percent will be equalled or exceeded 42.7 percent of the time (fig. 1). Also, there is a 50/50 chance of earning 4.9 percent or more, and two chances in three of earning 4.3 percent or more on the investment.

DISCUSSION

An investment in a slash pine plantation in the West Gulf region was used to illustrate the application of the Hertz method of risk analysis to forestry, and show what useful information it provides. This example was chosen because of its suitability for describing the steps involved in the method, and because it is a type of investment foresters are frequently called on to analyze.

The Hertz method is not limited to investments

Table 2.—*Expected slash pine plantation yields, in West Gulf, with associated probabilities of occurrence*

Volume class at 30 years (C cu. ft./acre)	Surviving trees	Ratio of pulpwood volume to sawlog volume	Probability of occurrence
15.1–20.6	200	75:25	.33
20.7–24.6	300	80:20	.50
24.7–28.6	400	85:15	.15
28.8–30.0	500	85:15	.02

Table 3.—*Expected value of output per cubic foot from slash pine plantation, in West Gulf, with associated probabilities of occurrence*

Value class	Ratio of pulpwood volume to sawlog volume			Probability of occurrence
	75:25	80:20	85:15	
		$/C cu. ft.		
Low	.220–.290	.195–.260	.170–.230	.25
Medium	.291–.360	.261–.320	.231–.280	.60
High	.361–.400	.321–.360	.281–.320	.10
Highest	.401–.500	.361–.460	.321–.420	.05

Table 4.—*Ranking from lowest to highest of frequencies with which rates of return occurred, based on 10,000 iterations, for slash pine plantation, in West Gulf*[1]

Rate of return (percent)	Rate of return in tenths of percent									
	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
	number									
0.00	0	0	0	0	0	0	0	0	0	0
0.01	0	0	0	0	0	0	0	0	0	0
0.02	0	2	0	1	2	5	7	10	11	20
0.03	26	39	38	67	71	87	105	134	153	196
0.04	211	274	271	322	355	388	419	403	433	453
0.05	471	505	482	503	465	453	374	345	267	237
0.06	186	160	117	88	82	63	51	31	29	31
0.07	21	14	5	3	3	4	1	2	0	1
0.08	0	0	0	0	0	0	0	0	0	0

[1]503 null iterations.

Table 5.—*Cumulative probabilities of occurrence by rates of return, based on 10,000 iterations, for slash pine plantation in West Gulf*

Rate of return (percent)	Rate of return in tenths of percent									
	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
0.00	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950
0.01	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950
0.02	0.950	0.950	0.950	0.949	0.949	0.949	0.948	0.948	0.946	0.945
0.03	0.943	0.939	0.936	0.930	0.923	0.915	0.906	0.894	0.880	0.862
0.04	0.842	0.818	0.790	0.761	0.727	0.690	0.649	0.608	0.566	0.522
0.05	0.476	0.427	0.378	0.328	0.280	0.234	0.193	0.157	0.126	0.101
0.06	0.080	0.063	0.049	0.039	0.030	0.023	0.017	0.013	0.010	0.007
0.07	0.004	0.003	0.002	0.001	0.001	0.001	0.000	0.000	0.000	0.000
0.08	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

in plantations as in the example, however. It can be used with capital outlays for a range of diverse purposes such as timber stand improvement, purchase of a feller-buncher, or installation of a chipping headrig.

In the example, the composite rate of return on investment was the criteria selected for assessment of the investment. The Hertz method, however, is not tied to this single yardstick. Other criteria such as payback, net present value or average rate of return can be used if preferred.

There are several respects in which the Hertz method is superior to conventional techniques for determining the profitability of investment proposals. One is that it utilizes all of the quantitative information available on costs, returns, and risks. It resurrects the early days of profitability analysis by using many possible values. In those times, foresters agonized over the selection of specific "most likely" values because so many values were possible. The risk analysis technique described here allows the use of all possible values weighted by their probabilities.

Also, the Hertz method not only displays conventional "likely" outcome, but specifies the chances of that result occurring. In addition, a variety of other choice criteria such as maximums, minimums, means or variance, together with their expectations, are also shown. The results, too, are more likely to approximate future outcomes than are predictions from conventional analysis (MacKinnon 1976).

Further, the risk analysis method can be used with either of the two types of investment decisions forest managers make. One is to accept or reject a particular proposition. The other, which is a more common type of decision, is to choose among alternative propositions. This involves comparisons of investment alternatives. The method can also realistically compare investments of different risk levels, long term investments with short term investments, and forestry with nonforestry investments.

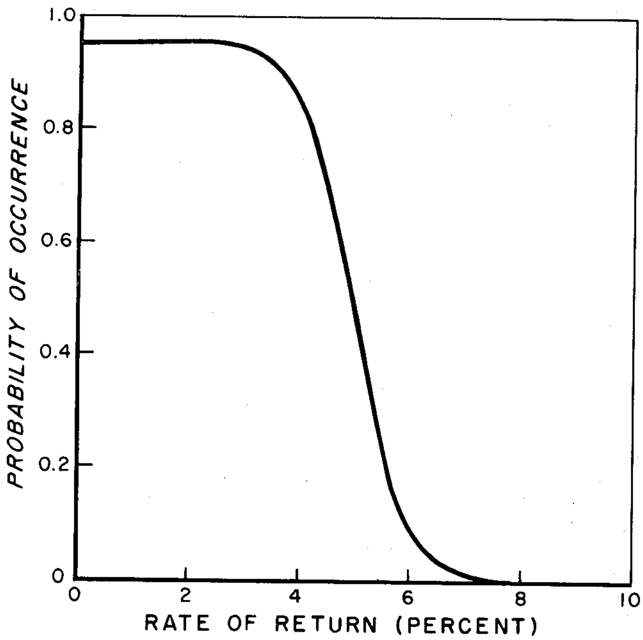

Figure 1.—*Risk profile for investment in the slash pine plantation based on cumulative probabilities for 10,000 iterations.*

An additional benefit of the technique is that it can show a decision maker the logical conclusion of a peculiar set of expectations. The individual can learn the chances of earning at least some particular rate of return for the magnitudes and probabilities that were indicated for the various prices and other factors. This approach is helpful, especially when the analysis can pinpoint a specific factor as the cause of most of the uncertainty.

Although the Hertz method is a powerful and highly useful method of risk analysis, it is based on subjective estimates of the likelihood of various values for determining variables. This is shown by the illustration. The subjective nature of the process is a principal reason the results imply lower rates of return than foresters familiar with the region would expect. Generalized regional data were used that, of necessity, exaggerated the risks for an individual firm. A forest manager usually has some control over certain aspects of risk. In the illustration, for instance, planting losses could be reduced by grading the seedlings and properly handling the stock between the nursery and the planting site. The assumption that the results of the risk analysis are representative of the "real world" may be incorrect.

Another example of how the process is based on subjective estimates of the likelihood of various values for determining variables is the group of stumpage values used in the illustration (table 3). These values cannot arise from any objective sampling of a future market, but are the decision maker's best guess about the likelihood of various prices occurring. This means that the probability function (fig. 1) derived from these estimates is also subjective, and therefore may not represent the real world as an objective function would. Also, in the subjective case, it is not possible to determine how closely the estimate approximates reality. A confidence band cannot be established around the curve.

The Hertz method of risk analysis provides a formal procedure for quantifying risk in forestry investments. It is a tool for major decisions. When properly used, it will enable forest managers to make better investment choices.

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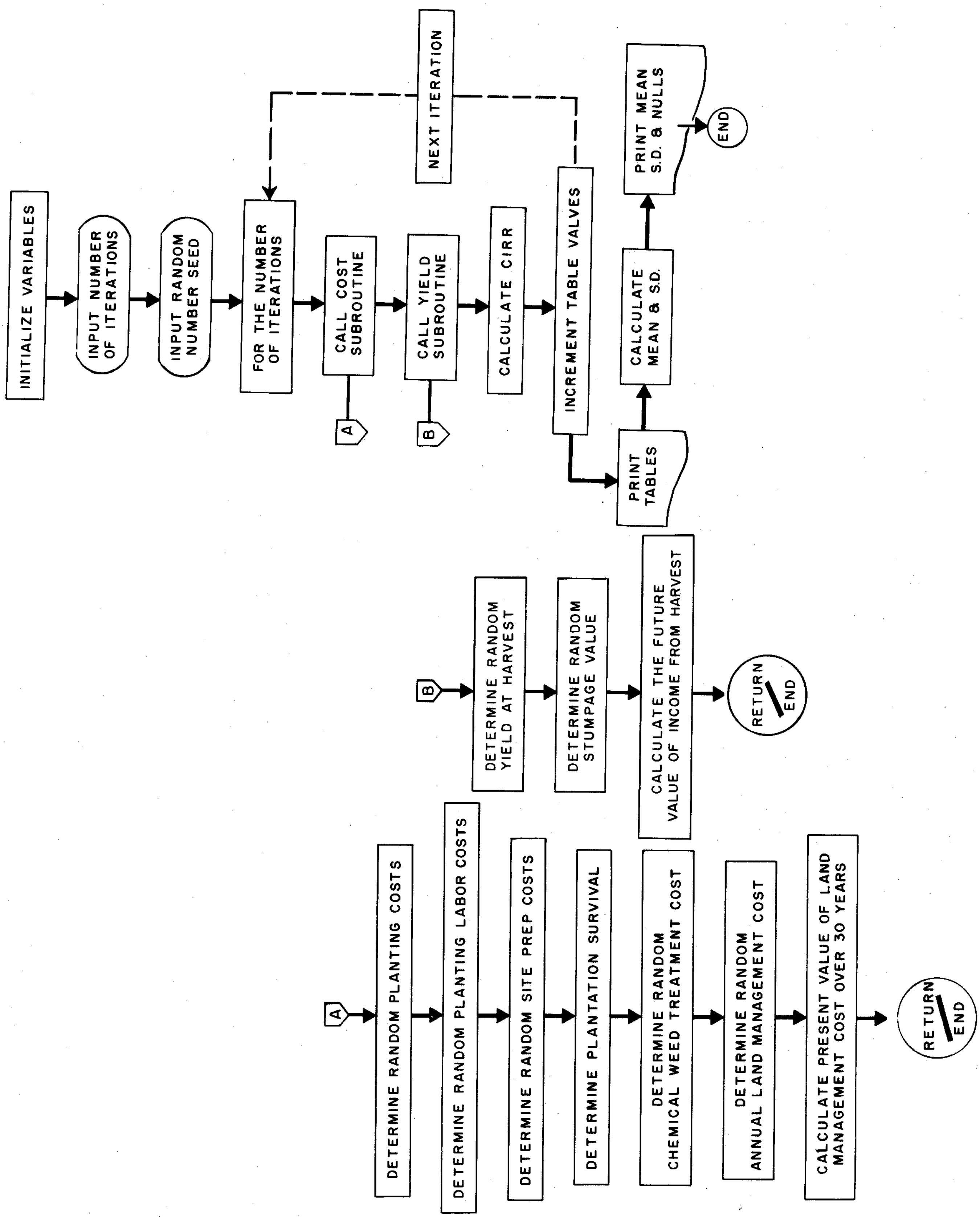
Appendix



INITIALIZE VARIABLES
INPUT NUMBER OF ITERATIONS
INPUT RANDOM NUMBER SEED
FOR THE NUMBER OF ITERATIONS
CALL COST SUBROUTINE
CALL YIELD SUBROUTINE
CALCULATE CIRR
INCREMENT TABLE VALVES
NEXT ITERATION
PRINT TABLES
CALCULATE MEAN & S.D.
PRINT MEAN S.D. & NULLS
END
A
B
DETERMINE RANDOM YIELD AT HARVEST
DETERMINE RANDOM STUMPAGE VALUE
CALCULATE THE FUTURE VALUE OF INCOME FROM HARVEST
RETURN END
DETERMINE RANDOM PLANTING COSTS
DETERMINE RANDOM PLANTING LABOR COSTS
DETERMINE RANDOM SITE PREP COSTS
DETERMINE PLANTATION SURVIVAL
DETERMINE RANDOM CHEMICAL WEED TREATMENT COST
DETERMINE RANDOM ANNUAL LAND MANAGEMENT COST
CALCULATE PRESENT VALUE OF LAND MANAGEMENT COST OVER 30 YEARS
RETURN END

```
C***********************************************************************
C-     HERTZ-MONTE CARLO PROFITABILITY MEASUREMENT
C-
C-     HMCPM IS A SIMULATION OF MANAGEMENT PROFITABILITY FOR PLANTED
C-     SLASH PINE IN THE GULF COAST.
C-
C-     DEVELOPED BY: ROBERT J. ENGELHARD
C-     PROGRAMMED BY: FREDERICK M. HILPERT
C-     UNIVERSITY OF WISCONSIN, STEVENS POINT
C-     1979
C-
C**********************************************************************
      REAL IRR
      DIMENSION ITAB(200),PERC(200)
      DATA ITAB/200*0/,SUM,SS,NULL/2*0.0,0/,PERC/200*0.0/
      OPEN (5)
      WRITE(6,3)
    3 FORMAT(' ','INPUT NUMBER OF ITERATIONS'/' --')
      READ(5,/)ITER
      WRITE(6,4)
    4 FORMAT('0','INPUT RANDOM NUMBER SEED(POSITIVE INTEGER)'/' --')
      READ(5,/)ISEED
      DO 15 M=1,ITER
        CALL COST(VAL,ISEED,IFLAG)
        CALL YIELD(YLD,IFLAG,ISEED)
C-
C-      CALCULATE INTERNAL RATE OF RETURN AND TABULATE
C-
        IF (YLD.NE.0.) GO TO 5
C-
C-      COUNT IF YIELD IS 0.0
C-
        NULL=NULL+1
        GO TO 15
    5   IRR=10.**(ALOG10(YLD/VAL)/30.)-1.
    7   SUM=SUM+IRR
        SS=SS+IRR*IRR
C-
C-     INCREMENT TABLE VALUE
C-
        BOT=-0.1005
        TOP=-0.0995
        DO 10 I=1,200
          IF (IRR.GT.BOT.AND.IRR.LE.TOP) GO TO 13
          BOT=BOT+.001
          TOP=TOP+.001
   10   CONTINUE
   13   ITAB(I)=ITAB(I)+1
C-
C-       NEXT ITERATION
C-
   15 CONTINUE
C-
C-     CONVERT THE ONE DIMENSION TABULATION ARRAY TO TABLE FORM
C-
      IF=1
      IL=10
      Y=-.10
      WRITE(6,20)
```

```
 20 FORMAT(///'0',T19,'FREQUENCIES OF RATES OF RETURN')
    WRITE(6,25)(I,I=0,9)
 25 FORMAT('0',6X,10('  .00',I1)/)
    DO 40 I=1,20
      WRITE(6,30)Y,(ITAB(J),J=IF,IL)
 30   FORMAT(' ',F5.2,1X,10I6)
      IF=IF+10
      IL=IL+10
      Y=Y+.01
 40 CONTINUE
C-
C-    CALCULATE CUMULATIVE PROBABILITIES
C-
    I=200
C-
C-    ASSUME 1/2 THE VALUES ARE ABOVE AND BELOW THE MID-POINT
C-
    CUM=0.0
 50 PERC(I)=(CUM+0.5*ITAB(I))/ITER
      CUM=CUM+ITAB(I)
      I=I-1
    IF (I.NE.0) GO TO 50
C-
C-    CONVERT AND PRINT
C-
    WRITE(6,60)ITER
 60 FORMAT(///'0',T11,'CUMULATIVE PROBABILITIES FOR',I6,
   *         ' ITERATIONS'/)
    WRITE(6,25)(I,I=0,9)
    IF=1
    IL=10
    Y=-.10
    DO 80 I=1,20
      WRITE(6,70)Y,(PERC(J),J=IF,IL)
 70   FORMAT(' ',F5.2,1X,10F6.3)
      IF=IF+10
    IL=IL+10
      Y=Y+.01
 80 CONTINUE
C-
C-    CALCULATE AVERAGE AND STANDARD DEVIATION
C-
    N=ITER-NULL
    AVG=SUM/N
    SD=SQRT((SS-(SUM*SUM)/N)/N)
    WRITE(6,90)AVG,SD,NULL
 90 FORMAT(///'0','AVERAGE=',F6.3//'0','S. D.=',F8.3//'0',
   *      'NULL ITERATIONS=',I6/////)
    CALL EXIT
    END
C-
```

```
C------------------------------------------------------------------------
C------------------------------------------------------------------------
C-
      SUBROUTINE COST(VAL,ISEED,IFLAG)
C-
C-    RETURNS PRESENT VALUE OF ESTABLISHMENT AND MANAGEMENT COST.
C-
C------------------------------------------------------------------------
C-
C-    DETERMINE PLANTING COST
C-
       X=RANDOM(ISEED)
      IF(X.GT.0.AND.X.LE..10)VAL=5.85
      IF(X.GT..10.AND.X.LE..30) VAL =7.15
      IF(X.GT..30) VAL=7.80
C-
C-    DETERMINE LABOR COST
C-
       X=RANDOM(ISEED)
      IF(X.GT..75) GO TO 10
      X=RANDOM(ISEED)
      XLAB=11.00+7.50*X
      GO TO 20
   10 X=RANDOM(ISEED)
      XLAB=22.00+3.00*X
   20 VAL=VAL+XLAB
C-
C-    DETERMINE SITE PREPARATION COST
C-
      X=RANDOM(ISEED)
      IF(X.GT..30) GO TO 30
      X=RANDOM(ISEED)
      SITE=73.01+6.99*X
      GO TO 50
   30 IF(X.GT..70) GO TO 40
      X=RANDOM(ISEED)
      SITE=67.01+5.99*X
      GO TO 50
   40 X=RANDOM(ISEED)
      SITE=60.00+7.00*X

   50 VAL=VAL+SITE
C-
C-    DETERMINE SURVIVAL
C-
      X=RANDOM(ISEED)
      IF(X.GT..18) GO TO 60
      IFLAG=1
      VAL=VAL+((VAL-SITE)/1.1)
      GO TO 80
   60 IF(X.GT..28) GO TO 70
      IFLAG=2
      VAL=VAL+((VAL-SITE)/(1.1**2))
      GO TO 80
   70 IFLAG=3
C-
```

```
C-     DETERMINE CHEMICAL WEED TREATMENT COST
C-
   80 X=RANDOM(ISEED)
      IF (X.GT.0.10) GO TO 85
      X=RANDOM(ISEED)
      CHEM=21.8+6.88*X
      VAL=VAL+CHEM/(1.1**5)
C-
C-     DETERMINE MANAGEMENT COST
C-
   85 X=RANDOM(ISEED)
      IF(X.GT..25) GO TO 90
      X=RANDOM(ISEED)
      CMAN=3.00+.5*X
      GO TO 130
   90 IF(X.GT..58) GO TO 100
      X=RANDOM(ISEED)
      CMAN=3.51+.49*X
      GO TO 130
  100 IF(X.GT..83) GO TO 110
      X=RANDOM(ISEED)
      CMAN=4.01+.49*X
      GO TO 130
  110 IF(X.GT..98) GO TO 120
      X=RANDOM(ISEED)
      CMAN=4.51+.99*X
      GO TO 130
  120 X=RANDOM(ISEED)
      CMAN=5.51+2.49*X
C-
C-    ITERATION OVER 30 YEARS
C-
  130 SUM=0.
      DO 140 I=1,30
        SUM=SUM+CMAN/1.10**(I-1)

  140 CONTINUE
      VAL=VAL+SUM
      RETURN
      END
C-
C------------------------------------------------------------------------
C------------------------------------------------------------------------
C-
      SUBROUTINE YIELD(YLD,IFLAG,ISEED)
C-
C-       RETURNS FUTURE VALUE OF INCOME FROM THE STAND
C-
C------------------------------------------------------------------------
C-
C-    DETERMINE VOLUME FOR 0-.33
C-
      X=RANDOM(ISEED)
      IF(X.GT..33) GO TO 70
      IF(IFLAG.NE.1) GO TO 10
      X=RANDOM(ISEED)
      VOL=1450+560*X
      GO TO 30
```

```
   10 IF (IFLAG.NE.2) GO TO 20
      X=RANDOM(ISEED)
      VOL=1400+560*X
      GO TO 30
   20 X=RANDOM(ISEED)
      VOL=1500+560*X
C-
C-     DETERMINE VALUE FOR 0-.33 VOLUME
C-
   30 X=RANDOM(ISEED)
      IF (X.GT..25) GO TO 40
      X=RANDOM(ISEED)
      VAL=.22+.07*X
      GO TO 250
   40 IF(X.GT..85) GO TO 50
      X=RANDOM(ISEED)
      VAL=.291+.069*X
      GO TO 250
   50 IF(X.GT..95) GO TO 60
      X=RANDOM(ISEED)
      VAL=.361+.039*X
      GO TO 250
   60 X=RANDOM(ISEED)
      VAL=.401+.099*X
      GO TO 250
C-
C-     DETERMINE VOLUME FOR .34-.83
C-
   70 IF(X.GT..83) GO TO 140
      IF (IFLAG.NE.1) GO TO 80
      X=RANDOM(ISEED)
      VOL=1991+399*X
      GO TO 100
   30 IF (IFLAG.NE.2) GO TO 90
      X=RANDOM(ISEED)
      VOL=1921+399*X
      GO TO 100
   90 X=RANDOM(ISEED)
      VOL=2061+399*X
C-
C-     DETERMINE VALUE FOR .34-.83
C-
  100 X=RANDOM(ISEED)
      IF (X.GT..25) GO TO 110
      X=RANDOM(ISEED)
      VAL=.195+.065*X
      GO TO 250
  110 IF (X.GT..85) GO TO 120
      X=RANDOM(ISEED)
      VAL=.261+.059*X
      GO TO 250
  120 IF (X.GT..95) GO TO 130
      X=RANDOM(ISEED)
      VAL=.321+.039*X
      GO TO 250
  130 X=RANDOM(ISEED)
      VAL=.361+.099*X
      GO TO 250
C-
```

```
C-     DETERMINE VOLUME FOR .84-.98
C-
  140 IF (X.GT..98) GO TO 180
      IF (IFLAG.NE.1) GO TO 150
      X=RANDOM(ISEED)
      VOL=2371+409*X
      GO TO 170
  150 IF (IFLAG.NE.2) GO TO 160
      X=RANDOM(ISEED)
      VOL=2281+409*X
      GO TO 170
  160 X=RANDOM(ISEED)
      VOL=2461+409*X
C-
C-     DETERMINE VALUE FOR .84-.98 (SAME PROCEDURE AS .99-1.00)
C-
  170 GO TO 210
C-
C-     DETERMINE VOLUME FOR .99-1.00
C-
  180 IF (IFLAG.NE.1) GO TO 190
      X=RANDOM(ISEED)
      VOL=2781+129*X
      GO TO 210
  190 IF (IFLAG.NE.2) GO TO 200
      X=RANDOM(ISEED)
      VOL=2691+129*X
      GO TO 210
  200 X=RANDOM(ISEED)
      VOL=2871+129*X
C-
C-     DETERMINE VALUE FOR .84-1.00
C-
  210 X=RANDOM(ISEED)
      IF (X.GT..25) GO TO 220
      X=RANDOM(ISEED)
      VAL=.17+.06*X
      GO TO 250
  220 IF(X.GT..85) GO TO 230
      X=RANDOM(ISEED)
      VAL=.231+.049*X
      GO TO 250
  230 IF(X.GT..95) GO TO 240
      X=RANDOM(ISEED)
      VAL=.281+.039*X
      GO TO 250
  240 X=RANDOM(ISEED)
      VAL=.321+.099*X
C-
C-     DETERMINE YIELD
C-
  250 YLD=VOL*VAL
      X=RANDOM(ISEED)
      IF(X.GT..95) YLD=0.0
      RETURN
      END

#ET=7:16.5 PT=5.1 IO=1.1
```

ENGELHARD, ROBERT J. and WALTER C. ANDERSON
1983. A method of assessing risk in foresty investments. U.S. Dep. Agric. For. Serv. Res. Pap. SO-189, 13p. South. For. Exp. Stn., New Orleans, La.

A practical procedure for computing the likelihood that expected returns will be realized.

Additional keywords: Uncertainty, Monte Carlo simulation, probability distribution curve.

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